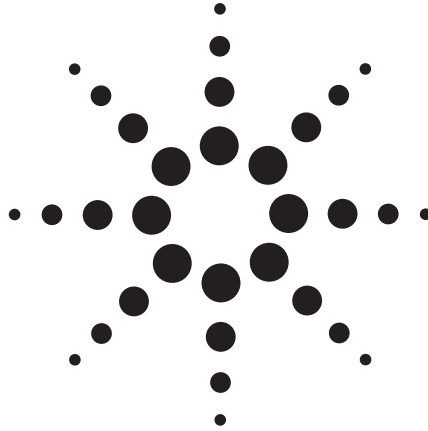


Resistance; DC Current; AC Current; and Frequency and Period Measurement Errors in Digital Multimeters

Application Note AN 1389-2



Introduction

When you make measurements with a digital multimeter (DMM), common errors will crop up. The following discussion will help you eliminate potential measurement errors and achieve the greatest accuracy with a DMM. This paper covers resistance; dc current; ac current; and frequency and period measurement errors. For a discussion of system cabling errors and dc voltage measurement errors, see Application Note AN 1389-1. For an overview of ac voltage measurement errors, see Application Note AN 1389-3. (NOTE: The Agilent 34401A, a 6-1/2-digit, high-performance DMM with both benchtop and system features, will be used as an example throughout this article).



Resistance Measurement Errors

The Agilent 34401A offers two methods for measuring resistance: *2-wire* and *4-wire ohms*. For both methods, the test current flows from the input HI terminal and then through the resistor being measured. For 2-wire ohms, the voltage drop across the resistor being measured is sensed internal to the multimeter. Therefore, test lead resistance is also measured. For 4-wire ohms, separate "sense" connections are required. Since no current flows in the sense leads, the resistance in these leads does not give a measurement error.

Errors for dc voltage measurements (see Application Note 1389-1) also apply to resistance measurements. However, there are additional error sources that are unique to resistance measurements.

Power Dissipation Effects — When measuring resistors designed for temperature measurements (or other resistive devices with large temperature coefficients), be aware that the multimeter will dissipate some power in the DUT. If power dissipation is a problem, select the multimeter's next higher measurement range to reduce the errors to acceptable levels. Figure 1 shows several examples.

Range	Test Current	DUT Power at Full Scale
100Ω	1 mA	100 μW
1 kΩ	1 mA	1 μW
10 kΩ	100 μA	100 μW
100 kΩ	10 μA	10 μW
1 MΩ	5 μA	30 μW
10 MΩ	500 nA	3 μW

Figure 1.

Settling Time Effects — The Agilent 34401A has the ability to insert automatic measurement settling delays. These delays are adequate for resistance measurements with less than 200 pF of combined cable and device capacitance, which is particularly important when measuring resistances above 100 kΩ. Settling due to RC time constant effects can be quite long. Some precision resistors and multi-function calibrators use large parallel capacitors (1000 pF to 0.1 μF) with high resistor values to filter out noise currents injected by their internal circuitry. Non-ideal capacitances in cables and other devices may have much longer settling times than expected just by RC time constants, due to dielectric absorption (soak) effects. Errors will be measured when settling after the initial connection and after a range change.

High-Resistance Measurement Errors — When you measure large resistances, significant errors can occur due to insulation resistance and surface cleanliness. You should take the necessary precautions to maintain a "clean" high-resistance system. Test leads and fixtures are susceptible to leakage due to moisture absorption in insulating materials and "dirty" surface films. Nylon and PVC are relatively poor insulators (10^9 ohms) compared to PTFE Teflon insulators (10^{13} ohms). Leakage from nylon or PVC insulators can easily contribute a 0.1% error when measuring a 1 MΩ resistance in humid conditions.

DC Current Measurement Errors

When you connect the multimeter in series with a test circuit to measure current, a measurement error is introduced, caused by the multimeter's *series burden voltage*. A voltage is developed across the wiring resistance and current shunt resistance of the multimeter, as shown in Figure 2.

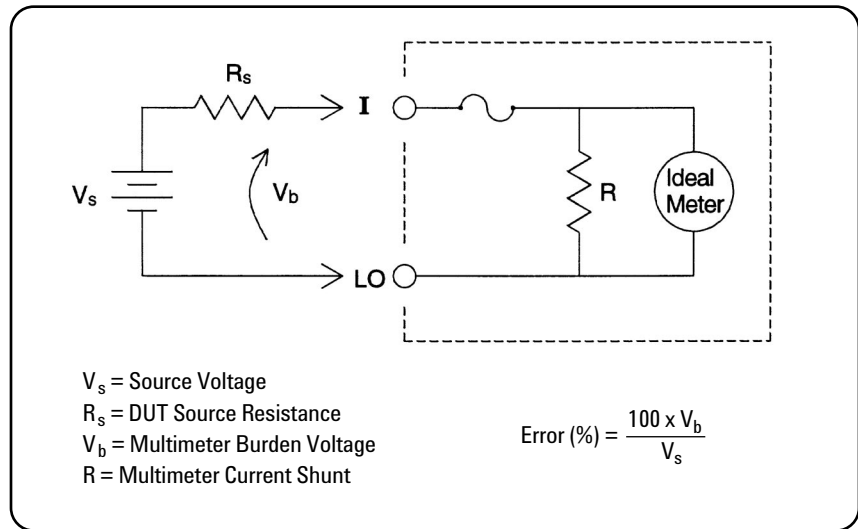


Figure 2.

AC Current Measurement Errors

Burden voltage errors, which apply to dc current, also apply to ac current measurements. However, the burden voltage for ac current is larger due to the multimeter's series inductance and the measurement connections.

The burden voltage increases as the input frequency increases. Some circuits may oscillate when performing current measurements due to the multimeter's series inductance and the specific measurement connections.

Frequency and Period Measurement Errors

The Agilent 34401A uses a reciprocal counting technique to measure frequency and period to generate constant measurement resolution for any input frequency. The 34401A's ac voltage measurement section performs input signal conditioning. All frequency

counters are susceptible to errors when measuring low-voltage, low-frequency signals. The effects of both internal noise and external noise pickup are critical when measuring "slow" signals. The error is inversely proportional to frequency. Measurement errors

will also occur when you attempt to measure the frequency (or period) of an input following a dc offset voltage change. To avoid this, allow the multimeter's input dc blocking capacitor to fully settle before making frequency measurements.

Conclusion

When measuring small resistance or low current, it is important to take extra precautions to make quality measurements. Once the system settling times have been determined, the reading delay times can be set to optimize measurement time and increase system throughput.

For more information about the Agilent 34401A DMM, go to www.agilent.com/find/34401a

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